Designing Chevyshev Band Pass Filters

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The purpose of this note is to demonstrate the options available in FAISYN which relate to the design and specification of bandpass filters and to re-acquaint the user with some of the general characteristics of Chebyshev filters.

More specifically, FAISYN will be used to design two Chebyshev band pass filters. This will require two passes through the program. At the end of each pass, a MMICAD simulation file will be created. The discussion will conclude with a comparison of the two filter responses.

Design Procedure

The design procedure is basically the same as that used in Application Note Nos. 3, 4 and 31. The user will specify the source and load resistances, the number of poles and the response type. FAISYN will synthesize a low pass prototype network. Next, the user will select a low pass to band pass transformation and input the band edge frequencies. FAISYN will then synthesize the final bandpass filter circuit.

All the band pass filters synthesised by FAISYN consist of a cascade of series and parallel LC resonators. An N-pole band pass filter will have a total of N resonators. When the source and load resistances are equal there will be two possible circuit configurations available, the difference being the type of leading resonator (see Figure 1).

In most cases filters are specified in terms of their 3dB frequencies. However when dealing with Chebyshev filters it is often desirable to specify the design in terms of the ripple edge frequency. Both options are avaiable in FAISYN.

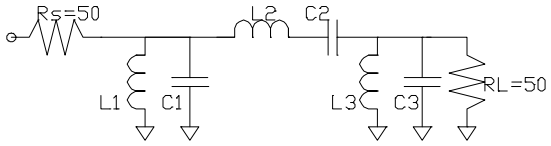
Circuit Specification

The first filter's bandwidth will be specified in terms of the upper and lower ripple edge frequencies. Furthermore, a shunt-series-shunt resonator circuit topology (see Figure 1a) will be used.

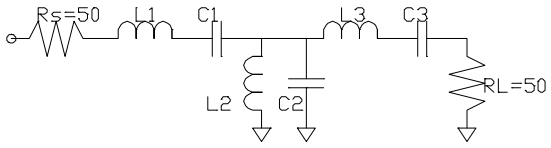
The bandwidth of the second filter will be specified in terms of its 3dB frequencies and the series-shunt-series resonator topology of Figure 1b will be selected. The rest of the specifications are summarized below.

FILTER 1
Response = 0.25dB ripple Chebyshev
Source resistance = 50 Ohms
Load resistance = 50 Ohms
Number of poles = 3
Lower ripple edge frequency = 850 MHz
Upper ripple edge frequency = 1150 MHz

FILTER 2
Response = 0.25dB ripple Chebyshev
Source resistance = 50 Ohms
Load resistance = 50 Ohms
Number of poles = 3
Center frequency = 1GHz
Lower 3dB frequency = 850 MHz
Upper 3dB frequency = 1150 MHz



(a) Three pole shunt-series-shunt resonator topology



(b) Three pole series-shunt-series resonator topology

Figure 1 Dual topologies for a 3-pole BP filter with equal terminations.

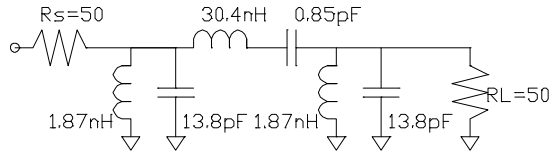
Band Pass Filter Synthesis using FAISYN

The first step is to enter the source and load resistances, the filter order N and the response type. The user will then input the in-band ripple (0.25dB) parameter and specifiy how band edges will be defined, i.e. ripple edge frequency for filter 1 and 3dB frequency for filter 2.

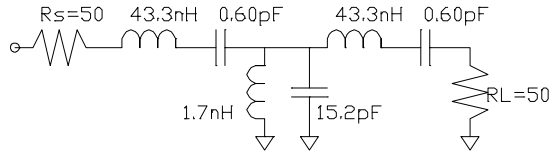
At this point FAISYN will prompt the user for the type of leading element in the normalized low pass circuit. Modern filter theory states that capacitors in the normalized low pass circuit transform to parallel LC's in the BP circuit and inductors in the low pass circuit transform to a series LC branch in the BP domain. This is important to remember because it means that the topology of the bandpass filter can be selected through the appropriate choice of leading element in the low pass prototype filter.

To realize Filter 1 with the topology of Figure 1a it is necessary to choose a capacitor as the leading element in the prototype circuit. Likewise, to realize the topology of 1b for Filter 2, the user must select a leading inductor in the prototype circuit.

After selecting the Band Pass transformation and entering the band edge frequencies, FAISYN synthesizes the final Band Pass Filters. These networks are shown in Figure 2.



(a) Band pass filter 1 using shunt-series-shunt topology.



(b) Band pass filter 2 using series-shunt-series topology.

Figure 2 Filter networks synthesized by FAISYN

MMICAD Simulation

To allow a more direct comparison of the final band pass filters, the two MMICAD circuit files created by FAISYN have been combined into the circuit file of Figure 3.

```
!====== FILTER SYNTHESIS PROGRAM V1.0 ========
! Example 3
! The MMICAD files created by FAISYN have been combined
! to allow comparision of the two filters designed in
! example 3.
! New File Name=EXAMPLE3.ckt
!
! Chebyshev Band Pass Filters
! N=  3
!  Lower ripple band edge frequency=  850.0000 MHZ
!  Upper ripple band edge frequency= 1150.0000 MHZ
! FILENAME= FILTER1.CKT
!  Chebyshev Band Pass Filters
! N=  3
!  Lower 3dB frequency=  850.0000 MHZ
!  Upper 3dB frequency= 1150.0000 MHZ
! FILENAME= FILTER2.CKT
!
!=======(c) 1992: OPTOTEK / K.FAISON =======

GLOBAL
 DIM  FREQ=1E6 CAP=1E-12 IND=1E-9

VAR
 RSOURCE= 50
 RLOAD= 50

CKT
! This filter specified in terms of ripple edge freq.
! Also parallel LC is first resonator

 PRLC 1  0 L=1.8738 C=13.8295
 SLC 1  2 L=30.4060 C=0.8522
 PRLC 2  0 L=1.8738 C=13.8295
DEF2P 1 2  FILTER1
! This filter specified in terms of 3 dB freq.
! Series LC is first resonator.

  SLC 1  2 L=43.3171 C=0.5982
 PRLC 2  0 L=1.7006 C=15.2381
 SLC 2  3 L=43.3171 C=0.5982
DEF2P 1 3  FILTER2

TERM
 FILTER1 RSOURCE RLOAD
 FILTER2 RSOURCE RLOAD

FREQ
 SWEEP  500 1500 5

OUT
 FILTER1 DB[S21] TRANS1
 FILTER1 DB[S11] TRANS1 R
 FILTER1 DB[S21] TRANS2
 FILTER1 DB[S11] TRANS2 R
 FILTER1 S11 SMITH
 FILTER2 DB[S21] TRANS1
 FILTER2 DB[S11] TRANS1 R
 FILTER2 DB[S21] TRANS2
 FILTER2 DB[S11] TRANS2 R
 FILTER2 S11 SMITH

GRID
 RANGE   500 1500 100
 TRANS1 -50 0 10 R -60 0
 RANGE   850.0000 1150.0000   50.0000
 TRANS2 -5  0 0.5 R -20 0

LABEL
Chebyshev Bandpass filters
```

The results of MMICAD simulation are shown in Figures 4, 5 and 6. Figure 4 is of particular interest because it clearly shows the ripple band edges of filter 1 and the 3dB band edges of filter 2. Also of interest is the Smith chart plot of figure 6, it shows the impedance of filter 1 approaching a short when moving out of band whereas the the impedance of filter 2 approaches an open. (Note that for passive circuits, the reflection coefficient moves in a clockwise direction as frequency increases.) This is a consequence of their respective circuit topologies.

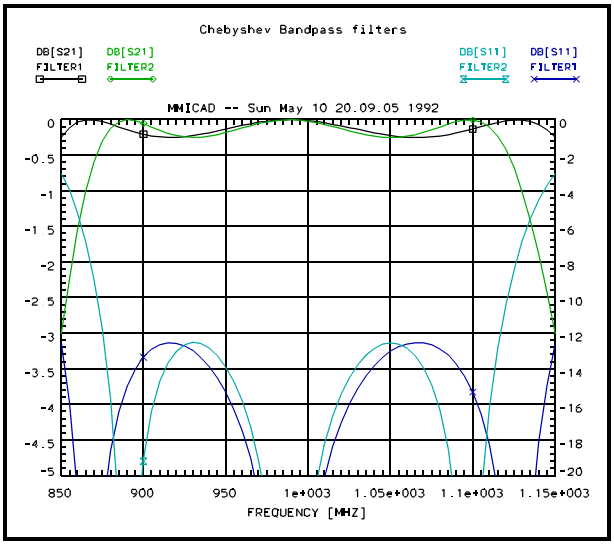


Figure 4 In band transmission response of filters 1 and 2.

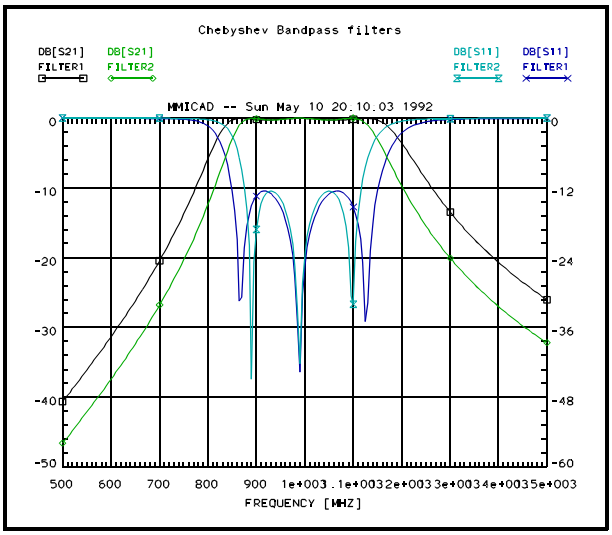


Figure 5 Broad band response of Chebyshev filters.

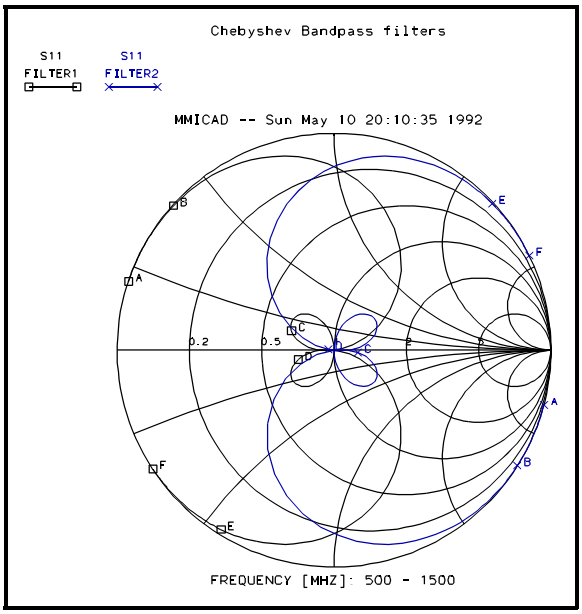


Figure 6 MMICAD plots of reflection coefficient